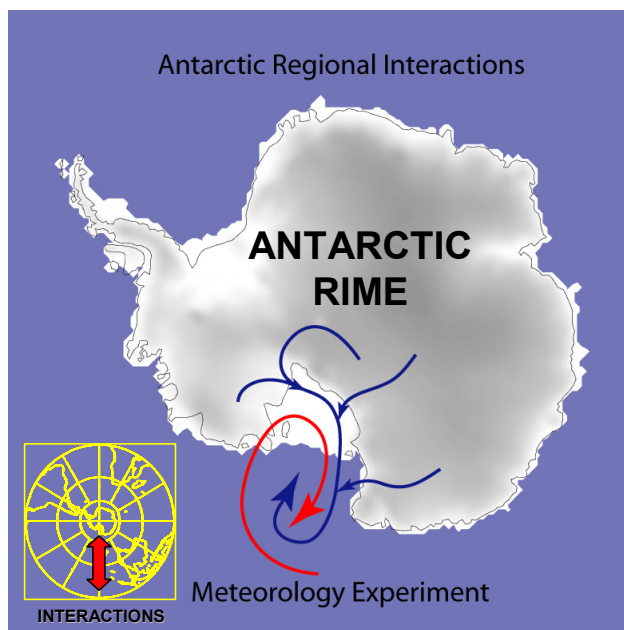


# **Antarctic Regional Interactions Meteorology Experiment (RIME)**



## **Implementation Plan**

Edited by David H. Bromwich and Thomas R. Parish

June 2004

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# ANTARCTIC REGIONAL INTERACTIONS METEOROLOGY EXPERIMENT (RIME) IMPLEMENTATION PLAN

**Overarching Hypothesis:** The Ross Sea region is critical in the exchange of mass, heat, moisture and momentum between the Antarctic continent and lower latitudes of the Southern Hemisphere on a variety of timescales, and dominates the polar direct circulation over Antarctica.

## 1. PROJECT DESCRIPTION

The *Antarctic Regional Interactions Meteorology Experiment* (RIME) is a basic and applied research program to explore in detail the local and regional atmospheric processes over Antarctica and their interactions with lower latitudes via the Ross Sea sector. RIME will consist of both observational and modeling components; fundamental goals include the study of physical processes in the lower atmosphere over the Ross Sea sector during episodes of extratropical cyclone forcing and simulation of such processes by atmospheric numerical forecast models. The RIME field phase will run from the austral summer of 2006-2007 through the spring of 2008. Details of the scientific objectives can be found in the *RIME Detailed Science Plan* that can be found at [http://polarmet.mps.ohio-state.edu/RIME-01/pdf\\_docs/rime\\_sciplan\\_all\\_final.pdf](http://polarmet.mps.ohio-state.edu/RIME-01/pdf_docs/rime_sciplan_all_final.pdf).

RIME will incorporate three field seasons, the austral summer periods of 2006-2007 and 2007-2008 and the austral springtime period of 2008. Field activities will use the home base at McMurdo Station with associated field activities at other sites over the Ross Ice Shelf. Five measurement strategies have been identified; the resulting data analyses will be used with state-of-the-art numerical modeling of the Antarctic environment.

Selection of the Ross Sea region of Antarctica is based on the emerging view that this region is critical in the transport of mass, heat and momentum between the Antarctic continent and middle latitudes of the Southern Hemisphere on a variety of scales. The Ross Ice Shelf is logistically accessible by the U.S. Antarctic Program, which can support the logistical needs of a large, multi-component field program such as RIME. An additional benefit for conducting RIME out of McMurdo will be the expected impact that model improvements and new data products will have on weather forecasting in support of operations in the vicinity of the Ross Sea.

Two scales of atmospheric processes, *regional* and *local*, will be considered during RIME. These two scales shape the experimental design of the program. The interaction of Antarctic processes with the meteorology of the subpolar latitudes of the Southern Hemisphere requires a *regional-scale* examination. The scope of RIME on this scale will encompass an area from the South Pole to approximately 65°S and from approximately 135°W to 135°E. The topics to be addressed on this scale include the (i) circumpolar vortex about Antarctica, (ii) topographically-induced mesoscale circulations, (iii) moist processes and cyclonic events and (iv) mesoscale cyclones. Although it is through this regional-scale that Antarctica communicates with the rest of the Southern Hemisphere, smaller scale processes such as the interaction of various mesoscale flows from the Ross

Ice Shelf Airstream (RAS); boundary layer transformations caused by cloud-radiation interactions, surface-air interactions and strong wind shear in the stably-stratified flow modulate the transport processes that take place along the western edge of the Ross Ice Shelf. Recognizing the importance of such interactions, a *local-scale* study will also be conducted during RIME. Extensive instrumentation will be deployed on the Ross Ice Shelf to study these local and regional scale processes.

This document describes the implementation strategy and timetable for the various observational and modeling components for RIME. It is recognized that this implementation plan cannot be rigid owing to changes in proposal funding issues, deployment and other logistical considerations and other external factors. It is the intent of the RIME Scientific Steering Committee that this document will be updated as needed, and so must be viewed as a “living” implementation plan.

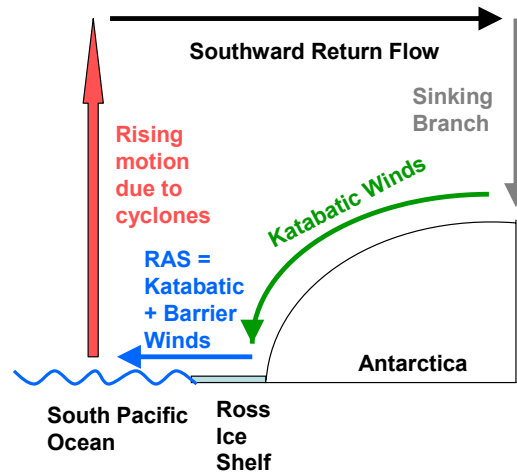
## **2. RESEARCH COMPONENTS OF RIME**

### ***2.1 Overview***

The RIME Detailed Science Plan lays out the following science topics that are integral to the polar direct circulation over Antarctica (Fig. 1):

- Boundary layer structure and transformation
- Local moist atmospheric processes
- Mesoscale cyclones
- Terrain-induced circulations
- Moist-processes and cyclonic events
- Circumpolar Vortex
- Hemispheric interactions

These science topics are elements of the Overarching Hypothesis. At the smallest scales, boundary layer structure and transformation along with local moist atmospheric processes generate the cold boundary layer air flows over Antarctica and are factors most poorly represented by numerical models. At somewhat larger scales are the mesoscale cyclones and terrain-induced circulations that act on the boundary layer processes to form the RAS. At synoptic scales oceanic cyclones advect warm, moist air southward and steer the cold, dry air of the RAS northward. Over time these large cyclones modulate the circumpolar vortex, which in turn affects hemispheric-scale climate variability, namely the Antarctic Oscillation and the El Niño-Southern Oscillation (ENSO). The Antarctic Oscillation is recognized as the leading mode of Antarctic circulation variability, and interacts with the tropical forcing from El Niño/La Niña events.



*Fig. 1. Schematic of the polar direct circulation over Antarctica emphasizing the Ross Sea sector.*

The following investigation approaches are proposed to address the RIME science topics and are described in detail in the following parts of Section 2:

- Regional surface-based array
- RIME Supersite
- Aircraft studies
- Modeling
- Remote sensing
- Climate studies.

The integrated nature of these approaches is demonstrated in Table 1; at least several are necessary to address each science topic.



Table 1. Relationship between RIME investigation approaches and science topics.

			Investigation Approaches					
			Regional Surface-Based Array	RIME Supersite	Aircraft Studies	Modeling	Satellite Remote Sensing	Climate Studies
Science Topics	Small Scale	Boundary Layer Structure and Transformation	X	X	X	X		
		Local Moist Atmospheric Processes	X	X	X	X	X	
		Mesoscale Cyclones	X	X	X	X	X	
		Terrain-Induced Circulations	X	X	X	X		X
		Moist-Processes and Cyclonic Events	X	X	X	X	X	X
		Circumpolar Vortex	X	X	X	X	X	X
	Large Scale	Hemispheric Interactions			X	X	X	X

## 2.2 Surface-Based Observations

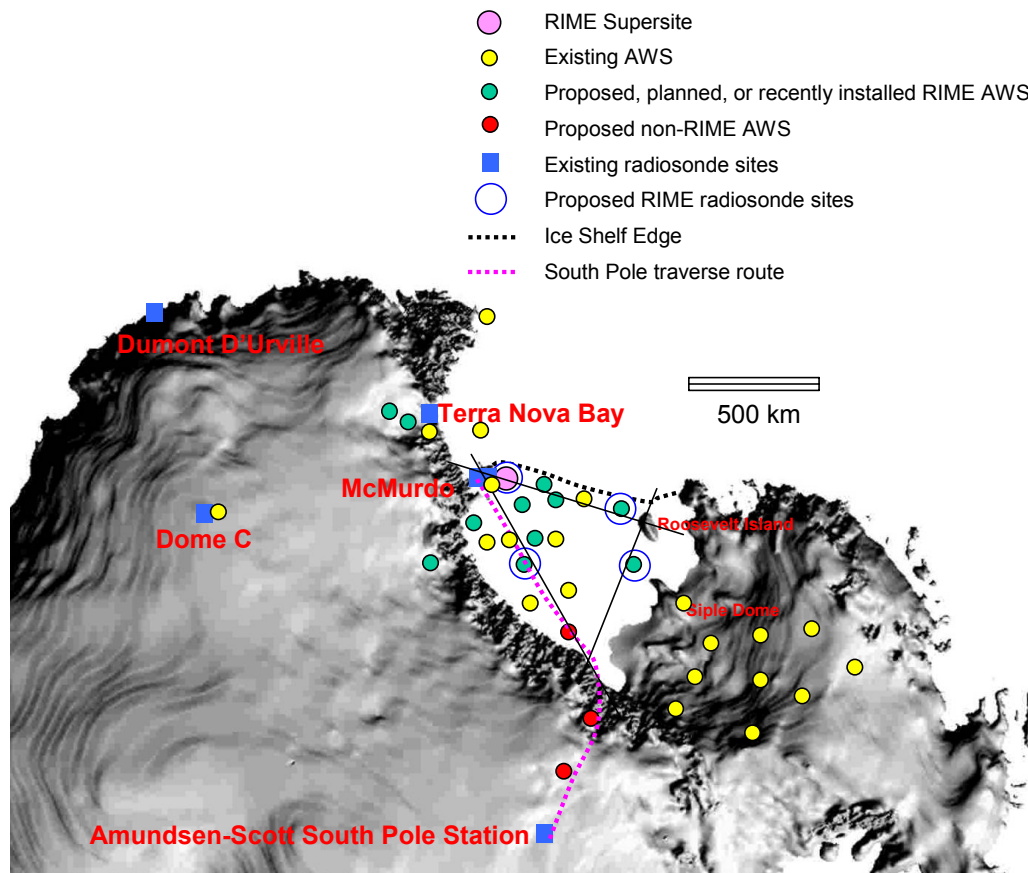
The Detailed Science Plan for RIME identifies key research questions that can be addressed in the Ross Island area of Antarctica. Deployment of a variety of surface-based instrumentation will take place at field sites in the Ross Island area. These will include automatic weather stations (AWS) to sample the surface environment, radiosonde launching facilities to depict the vertical structure of the atmosphere, and broadband radiometers to measure shortwave and longwave radiation. The primary goal of the surface-based studies of RIME is to provide a comprehensive data set to help address issues proposed in the Detailed Science Plan including a detailed observational network for use in modeling studies. In addition, surface deployments will add a “spatial context” to the RIME Supersite by placing key instrumentation in areas of maximum atmospheric variability. Among the key scientific issues driving surface-based observations are a need to understand the moisture flow across the edge of the Ross Ice Shelf, and to characterize the katabatic air flow off the high polar plateau. It is expected that the surface-based observational strategy will take advantage of existing and potential logistical opportunities with USAP.

Figure 2 shows a map of the planned measurement sites for surface-based studies during RIME. As stated in the Science Plan, RIME will focus on two spatial scales. The regional scale is defined by the five baseline stations: McMurdo, South Pole, Dome C, Dumont d’Urville, and Terra Nova Bay. As of 2004, radiosondes are being launched routinely at all of these stations, except for Dome C. There are plans to begin routine radiosonde launches at Dome C in the near future, before the RIME field seasons begin.

The local scale for RIME is depicted as a triangular area on the Ross Ice Shelf (Fig. 2). Each of the three sides of the triangle will experience a combination of unique

atmospheric events. The side along the northern edge of the ice shelf will be important for measuring the meridional fluxes of heat and moisture, with the flux magnitudes being modulated by the interplay between onshore flow from developing low pressure systems and outflow from katabatic flow off the high polar plateau. The western side of the triangle will sample flow along the Ross Ice Shelf Air Stream (RAS) and katabatic flow from the Transantarctic Mountains. The eastern side will be influenced by katabatic flow off Siple Dome and West Antarctica. Meteorological data from this area will be useful to the glaciological community because of past activity in obtaining ice cores in this region.

The large, pink circle depicts the approximate location of the RIME Supersite, the site of extensive micrometeorological measurements to be conducted as part of RIME. It will tentatively be located approximately 150 km from McMurdo. This location was chosen to minimize possible topographic effects from Ross Island, but also to place the Supersite instrumentation in a region of high atmospheric variability. It is believed that this location will experience a wide variety of weather conditions during the RIME field seasons, including air flow from the south due to the Ross Ice Shelf air stream, as well as significant onshore moisture events resulting from areas of low pressure located offshore.



*Figure 2. Planned measurement sites for RIME field instrumentation deployments (surface-based studies). A collection of existing AWS are shown as small, yellow circles. There are many additional AWS in the Ross Island area that are not shown.*

### *2.2.1 Automatic weather stations*

The red circles represent non-RIME AWS that will be deployed at the south end of the Ross Ice Shelf along the new South Pole traverse route (dashed magenta line). These are located in areas of interest for RIME, and will obtain data that will be available for RIME scientists. One is located at the base of the Leverett Glacier, one is at the top of the glacier, and one is halfway between the top of Leverett Glacier and South Pole Station. These three weather stations should experience, to varying degrees, air flow from the high plateau.

Green circles depict locations where RIME AWS are proposed, planned, or recently installed. Some of the new AWS will be equipped with additional instrumentation, including upward and downward-looking broadband shortwave and longwave radiation sensors, acoustic depth gauges, and an additional water vapor sensor. The AWS deployments fall into two broad categories: 1) AWS to complete the RIME triangle, and 2) strategically-placed AWS to sample special atmospheric phenomena.

Deployment of two AWS along the northern edge of the Ross Ice Shelf was completed during the austral summer season of 2003-2004. Four additional AWS will be deployed during the austral summer of 2004-2005. These four additional AWS will be deployed near the mouth of the Mullock Glacier, just west of Roosevelt Island, between existing AWS sites Schwerdtfeger and Gill, and along the proposed South Pole Traverse route halfway between the Marilyn and Elaine AWS sites. One AWS will be placed near either the old Siple Dome station or Onset Delta to complete the eastern side of the triangle in an upcoming field season. Additional stations may be deployed during the RIME initial field campaign. Aircraft or helicopter support may be requested at times to service remote AWS that are essential to attaining RIME's goals. These requests will be made only in the event of the loss of critical instrumentation.

Additional AWS will be placed in strategic locations. One will be situated on either Franklin Island or Inexpressible Island to sample the area of active cyclogenesis. In addition, stations will be placed high on the plateau above Byrd Glacier and Reeves Glacier. The AWS along Reeves Glacier will tie in nicely to a separate AWS network operated by the Italian Antarctic Program (PNRA) (not shown on Figure 2), and will sample katabatic flow off the plateau and into the area of offshore cyclogenesis.

### *2.2.2 Radiosondes*

In addition to the deployment of AWS, RIME will institute a radiosonde program to enhance our understanding of the vertical structure and upper air flow over the Ross Ice Shelf. Profiles of temperature, humidity, and wind speed and direction, obtained at strategically-chosen locations on the Ice Shelf, will provide new information about how katabatic flow interacts with cyclonic circulation patterns setup by synoptic storms.

The blue open circles indicate where sondes will be launched during the RIME field seasons. It is anticipated that sondes will be launched at least twice per day at each of the five baseline stations, plus an additional four locations on the Ross Ice Shelf, at 0000 and 1200 UTC, so that the vertical profiles will be available for initialization of weather forecasting models on a regular basis. RIME will be responsible for staffing the four additional sites on the Ice Shelf. The RIME radiosonde stations will also participate in

Intensive Observation Periods (IOPs) with up to eight (8) sondes launched within a 24-hour period. The personnel at these sites will be trained to make accurate visual sky observations. These observations will be made at least every hour during the RIME field seasons.

The four RIME radiosonde sites will be located at the Supersite, Roosevelt Island, Siple Dome/Onset Delta, and along the South Pole traverse route. Since these sites will have power for sonde operations, they will also be equipped with additional sensors beyond what will be available on the AWS. These include upward and downward-looking broadband shortwave and longwave radiation sensors. These sensors can then be outfitted with heaters and aspiration fans to keep the instruments free of rime and frost. Sonic anemometers will also be deployed, along with high-accuracy water vapor sensors. The personnel at these stations will also be responsible for measuring precipitation and the characteristics of the surface snow (density and snow-grain size).

### *2.2.3 Communications*

A key component of the RIME surface-based studies will be communicating the data in real-time back to McMurdo for assimilation into weather forecasting models. Therefore, it will be essential for the RIME instrument team to interface with Raytheon Polar Services via the RIME Science Management Office (see Section 3.2) to explore effective ways for transmitting data from the field to McMurdo. This might include the use of telex connections, satellite phones, and/or HF radios.

As mentioned above, it is essential that high-quality data communications be setup between each of the field camps and McMurdo, so that real-time data can be transferred. It is not only essential for data to be downloaded from the field camps to McMurdo, but also uploaded from McMurdo. Specifically, RIME personnel in the field will need frequent satellite images uploaded from McMurdo to prepare real-time measurement strategies (perhaps twice daily at 200 kilobytes per image). Therefore, each data connection from McMurdo to the field camps should have sufficient bandwidth to handle a few megabytes of data each day.

### *2.2.4 Measurement priorities*

Below is a list of the measurement priorities for the surface-based studies during RIME. These priorities reflect the priorities of the Science Plan to understand: 1) moist processes and the influence of mesoscale cyclones, 2) the RAS and terrain-induced circulations, and 3) boundary-layer structure and transformation, as well as clouds and precipitation over the Ross Ice Shelf.

- 1) Radiosonde launches at the Supersite.
- 2) Radiosonde launches at Roosevelt Island.
- 3) AWS along the edge of the Ice Shelf, between the Supersite and Roosevelt Island.
- 4) Radiosonde launches at the site along the South Pole traverse route.
- 5) AWS along the South Pole traverse route.
- 6) Radiosonde launches at Siple Dome/Onset Delta.
- 7) AWS along Reeves Glacier.

## 8) AWS above Byrd Glacier.

### *2.2.5 Logistical requirements, including forecast support*

The surface-based studies of RIME will be able to take significant advantage of existing logistical opportunities. In particular, RIME will benefit tremendously from the deployment of four key AWS at Roosevelt Island and in the vicinity of the Leverett Glacier. Also, if the South Pole traverse becomes a feasible transportation route in the near future, RIME will benefit greatly from placing AWS along this route. This will make it possible to service these stations without the need for expensive aircraft, such as helicopters. It will also make it easier to setup and supply the radiosonde station along this route.

### *2.2.6 Field camps*

The most significant logistical requirement will be the construction of the Supersite. The ability to launch radiosondes at this site is essential for the surface-based studies. It is preferable to have a covered building from which sondes can be prepared out of the wind. This building will not require heat, because sondes are prepared at ambient temperature. It could simply be a three-sided building with enough headroom to fill a weather balloon, and a large enough opening at one end to launch the balloon. On the other hand, the receiving equipment will need to be housed in a heated building, perhaps a Jamesway tent. The Supersite must be able to accommodate 15 to 20 people.

The Supersite should have a flagged road from McMurdo. This will facilitate the transport of personnel and equipment via ground vehicles, eliminating the need for aircraft support. There may be a lot of personnel turnover at the Supersite, so it will be essential to be able to transport people easily back and forth.

Similar facilities are required at the other three radiosonde sites on the Ice Shelf. Each of these three sites must have accommodations for 4 to 5 people. These sites should be equipped with 5 kW generators (and fuel) to be used for heating of the accommodations and power supplies for the instrumentation.

## ***2.3 RIME Supersite***

While the measurements at the RIME Supersite are expected to provide data relevant to numerous objectives within those for the local and regional atmospheric processes described in the RIME Detailed Science Plan, the emphasis at this site will be on those related to local atmospheric processes and the interaction between the local and regional processes. The location of the Supersite and the instrumentation deployed at this site are determined by these science objectives.

The study of local atmospheric processes will be emphasized at the RIME Supersite, with studies of the boundary-layer structure and transformations being a focus. The boundary-layer structure and processes over the Ross Ice Shelf are unknown as no measurements of this kind have been made on the Ross Ice Shelf away from the unique region near McMurdo Station and Williams Field. The boundary-layer objectives for the

Supersite include objectives for the snow surface, the atmospheric surface layer, the atmospheric boundary-layer, and clouds and radiation. Interactions between the boundary-layer structure and processes and regional processes will also be studied at the Supersite.

### *2.3.1 Studies of the snow surface*

To represent surface energy fluxes over Antarctica using regional and global scale climate models, it is necessary to understand all terms in the surface energy budget (SEB) and their spatial and temporal variability. The conductive heat flux in the snow, the incoming and outgoing longwave and shortwave radiation, the turbulent heat and moisture fluxes and the "ground" heat storage all need to be measured and the processes leading to their variability understood. Questions to be answered include: what is the relative importance of the various terms of the SEB for the Ross Ice Shelf? What processes modulate the various terms, and what processes lead to transformations such as surface melt? If surface melt occurs, how much energy is available? What is the albedo, an important parameter in climate models, and what causes its variability? How do changes in the SEB modulate surface processes such as drifting snow and snow metamorphosis? How are the changes in surface radiation and SEB related to the macro and microphysical characteristics of the clouds, the vertical thermal structure, and the meso and synoptic scale environment? While many of these processes have been studied elsewhere, the relative importance of the different process are likely different in this unique environment. Understanding such processes and evaluating forecast and climate model performances requires that each of the five major energy budget components is measured independently.

While the significance of blowing and drifting snow on transportation and human activity on the Ross Ice Shelf is clear, the ultimate consequences of blowing snow transport and sublimation for the surface mass and heat budget of the Antarctic Ice sheet is unknown. Despite the potential significance of these processes and a large volume of research, the answer to this question is unclear. Various previous experiments and theoretical studies have established bulk formulae and basic controls on blowing snow transport and sublimation. Recent studies have argued that the atmospheric surface layer becomes saturated from blowing snow sublimation, hence making this is a self-limiting process. However, a significant water vapor loss must still exist just above the saturated surface layer. The reasons for this are: in typical inversion conditions, warmer temperatures exist above the surface promoting subsaturated air; stronger winds exist above the lower part of the surface layer where the maximum blowing snow concentrations exist; vertical sensible heat flux divergence occurs above the low level jet and promotes water vapor transport away from the surface; and there must also be a momentum flux directed away from the surface above the low level jet.

To understand the processes influencing blowing snow initiation and provide data necessary for the development of a detailed parameterization of the effects of blowing snow for inclusion in regional and global climate models, specific standard measurements will be made at the Supersite in addition to the surface energy budget measurements. These include the age and hardness of the snow, the drifting snow mass flux, and the sublimation mass and latent heat flux contributions of blowing snow. To further

understand the moisture cycle, micro to continental scale estimates of the portion of the water vapor lost from the surface and later deposited (i.e., recycled) will be made. This question can be approached using water vapor budget techniques, as long as the simulations of water vapor transport and sublimation are accurate.

To further understand the moisture cycle over the ice shelf, measurements of water vapor transport within the snow are needed to elucidate the relative contribution of deep-snow water to the surface moisture flux to the atmosphere. An enhanced understanding of the deep-snow water vapor flux could also enhance our understanding of isotopic transport, with potential implications for ice core interpretations.

### *2.3.2 Studies of the atmospheric surface layer*

The turbulent momentum and sensible and latent heat fluxes are poorly represented over the continental ice sheets. Models either underpredict or overpredict these fluxes owing to poor knowledge of such parameters as surface roughness, transfer coefficients, vertical temperature structure (e.g., inversion strength), and vertical humidity profile. Flux transfer coefficients are especially poorly known for stable and very stable environments such as that over the ice shelf. The variability of each of these can be observed individually by RIME measurements to provide the needed constraint on the models. Gravity waves are suspected to contribute significantly to surface fluxes in regions of the Antarctic close to significant terrain) but may contribute much less over the relatively flat Arctic pack ice. It is unknown whether fluxes over the Ross Ice Shelf are influenced by gravity waves. If they are, what are the sources for such waves and under what conditions do they occur? Can their effect be parameterized? In addition, having multiple levels of turbulent flux measurements will allow us to assess the vertical heat and momentum flux divergence, the depth of the surface layer (the layer of constant flux), and the spatial "footprint" of the surface fluxes. These can all be used to validate models of surface atmosphere interactions from the micro- to macro-scales. Furthermore, the effects of gravity waves and the height of the surface layer will provide information on the appropriateness of the use of turbulent flux schemes based on Monin-Obukhov Similarity Theory. It is expected that the surface fluxes, surface-layer depth, and presence of gravity waves will be related to the presence of a RAS and the synoptic and mesoscale environment. Processes leading to these relationships will be explored. Furthermore, an annual cycle of these processes and features is expected, and may be explored by leaving some limited instrumentation at the Supersite during at least one winter during RIME. Flux measurements at portable automated measurement stations sited a few kilometers from the Supersite will be used to provide spatial information on the surface fluxes and to assess the representativity of the point flux measurements at the Supersite.

Silhouette and/or microtopographical measurements could provide a link between the effective surface roughness length of the surface and the actual topographical roughness. A physical basis for the surface roughness length would represent a breakthrough in micrometeorology.

### *2.3.3 Studies of the atmospheric boundary-layer*

The basic structure of the atmospheric boundary-layer (ABL) above the surface layer is unknown over the Ross Ice Shelf, as no experiment on the scale of RIME has ever been performed. The vertical ABL structure for RAS events, onshore flow, and quiescent on-shelf air masses need to be documented. For RAS events, questions include: Is the ABL multi-layered, since airstreams from various source regions merge upstream of the Supersite? What is the vertical distribution of blowing snow in RAS? Do vertical turbulent mixing and blowing snow both contribute to making the RAS appear warm in satellite thermal imagery? Are RAS significant generators of gravity waves? How does RAS flow influence surface fluxes? Other questions relevant to all flow regimes include: What is the time evolution of the ABL? How is the ABL structure modulated by time evolving mesoscale or synoptic-scale systems? How does the local ice shelf ABL modify mesoscale and synoptic-scale systems as they move over the ice shelf from the Ross Sea? What is the vertical structure of fluxes throughout the boundary-layer? Are there fluxes between the ABL and free troposphere? How are these flux profiles modulated by mesoscale and synoptic-scale events?

### *2.3.4 Studies of clouds and radiation*

The ABL is often related to the location, formation, and dissipation of clouds. Whether clouds are formed through ABL processes over the Ross Ice Shelf is not obvious, as the Ross Sea rather than the ice shelf is probably the main source of moisture. Questions that need to be answered include: what is the relative position of clouds within and above the ABL? Do ABL processes produce and dissipate clouds, or are clouds mainly confined to above the ABL? How frequently does diamond dust occur and what ABL process produces it?

Because the clouds can link the SEB and ABL processes over the Ross Ice Shelf to synoptic and mesoscale scale phenomena that produce the clouds, measurements of the cloud macro- and microphysical properties are needed to understand these links on various time scales. The macrophysical properties that influence the radiative effects of clouds include cloud amount, cloud phase, cloud base, cloud top, and cloud layering. Microphysical properties include optical depth, effective cloud particle radius, liquid water content and ice water content. Furthermore, time-height observations of basic meteorological parameters (e.g., wind speed and direction, temperature, humidity, vertical air velocity, precipitation rate) in addition to these cloud parameters allow an assessment of dynamical and turbulent processes producing the cloud characteristics and interacting with the local ABL. Important questions to answer include: What synoptic and mesoscale processes modulate the cloud properties and hence the surface radiation? Are dynamical or turbulent process important for interactions between the ice-shelf ABL and these synoptic and mesoscale phenomena, thereby modifying either the ABL or these phenomena (or both)? What dynamical process lead to precipitation? Do layers of potential instability aloft produce shallow convection and enhanced surface precipitation as seen in mid-latitude cyclones? Or is precipitation principally generated by more stable processes such as symmetric instability or quasi-geostrophic forcing? How far over the ice shelf is the moisture and instability from the Ross Sea important for cloud and



precipitation generation? How quickly is this Ross Sea air modified? Is the Ross Sea the main source of moisture for clouds and precipitation on the Ross Ice Shelf? How much do surface moisture fluxes from the ice shelf contribute?

### *2.3.5 Contributions to regional-scale processes and modeling studies*

In addition to providing measurements addressing science issues for local atmospheric processes, the measurements at the Supersite will also contribute to addressing questions regarding regional atmospheric processes. Some of these have already been discussed above, such as the structure of the RAS or the interactions between the on-shelf flow and the shelf precipitation, ABL, and SEB. The RAS is a terrain-induced circulation, and the latter clearly relate to moist processes, cyclonic events, and mesoscale cyclones. Profiling measurements from soundings and the remote sensors at the Supersite will also enhance to the satellite and aircraft measurements of the circumpolar vortex, as the meridional gradient of this vortex will likely be near the Supersite location. Also, Supersite data will provide data for parameterization development and model validation for models and parameterizations of local, regional, and large-scale processes. Some specific examples, such as surface flux and blowing snow parameterizations are mentioned above. Other examples would be to provide validation data for regional simulations of RAS events or mesoscale cyclones moving over the ice shelf from the Ross Sea. Clearly, for the regional or larger-scale modeling efforts, the data from the Supersite would be used in conjunction with the data from the distributed surface stations, the aircraft, and the satellites to be obtained during RIME.

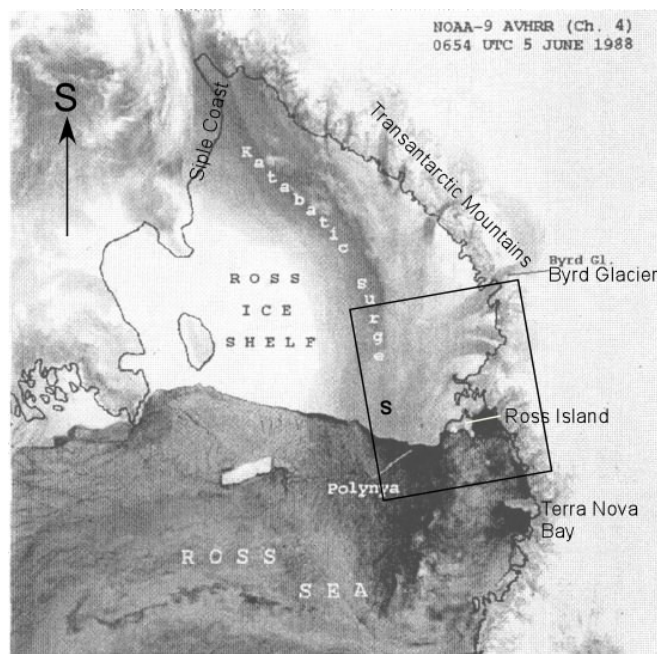
### *2.3.6 Supersite Location*

In order to maximize the utility of the data obtained at the Supersite for the science issues described above, its location is important. We propose that this Supersite be located about 160 km east of McMurdo within the typical path of the RAS (Fig. 3) and within 50 km of the edge of the Ross Ice Shelf to examine the on-shelf flow from the Ross Sea and mesoscale cyclone events (Fig. 4). This would put the site at approximately 79°S, 172.5°E, east of Ferrell AWS site and north of the new Emelia AWS site (Fig. 5). However, logistical considerations (crevasse fields, possibility of ice-shelf calving) when placing the Emelia site may suggest that a reconsideration of this placement is necessary. A possible alternative is for the Supersite to be placed at the Emelia AWS site. A placement at the "S" site shown in Fig. 5 would produce a spatial array of AWS sites with which gradients from three directions could be obtained. A placement at the Emelia site would provide some historical context data to the measurements at the Supersite and would be closer to the South Pole traverse. Either site should be close enough to be supplied by helicopter and surface vehicles.

The Supersite will be a station manned by several scientists and several engineers. It will need to have huts and tents for sleeping, eating, and laboratory space. In addition, unmanned remote sites with some limited instrumentation will be located within 25 km along an E-W line centered on the Supersite.

### 2.3.7 Instrumentation

To achieve the objectives described above, the instrumentation at the Supersite will consist of a large variety of in-situ and remote sensing instrumentation and will obtain measurements from the lower stratosphere to within the snow pack on the Ice Shelf (Table 2). It is desirable that some of the instruments will obtain redundant measurements, as this assures data in case of system failures and provides the possibility of data quality assessments. Furthermore, many of the instruments measuring the same parameter are often not precisely redundant as they frequently offer different spatial and temporal resolutions and different accuracies (e.g., wind profiler and scanning radiometer vs. soundings). Many of them complement each other, such as the sodar providing detailed wind profiles at heights below the lowest gates of the wind profilers. The surface temperature ( $T_s$ ) is a crucial parameter for the development of surface flux



*Figure 3. Thermal infrared satellite image of the Ross Ice Shelf at 0654 UTC 5 June 1988 showing a katabatic surge across the shelf from West Antarctica. (From Bromwich et al 1994) The proposed Supersite location is marked by "S".*

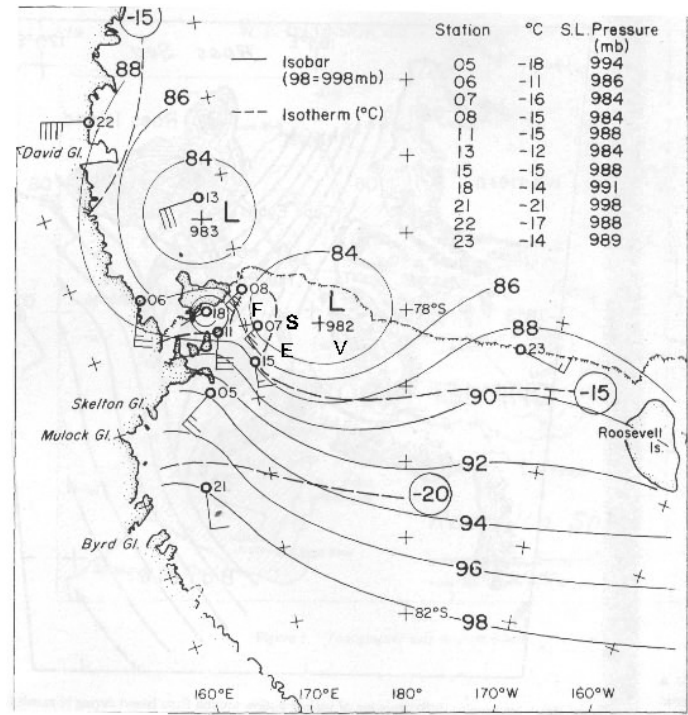


Figure 4. Sea-level pressure analysis for the western Ross Sea and Ross Ice Shelf, 00 UTC Feb 22, 1984. The proposed Supersite location is marked by "S". The recent AWS sites at Emilia (E) and Vito (V) are also shown.

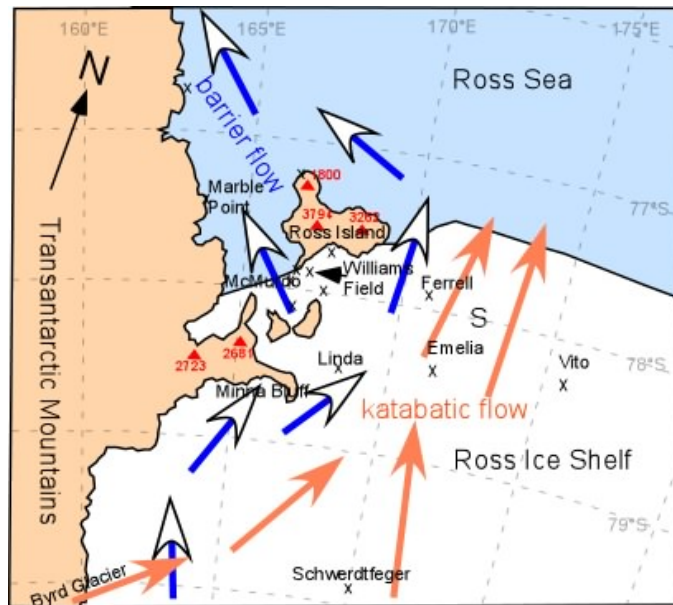


Figure 5. Map of the Western Ross Ice Shelf area showing Ross Island and McMurdo Station. The red triangles show peaks in the area with heights given in meters. The large arrows indicate the typical orientation and location of the katabatic flow (red closed arrows) and the barrier flow (blue open arrows) in the region. The proposed Supersite location is marked by "S".

parameterizations and is also a typically difficult parameter to measure accurately. Hence, measurements of  $T_s$  will be made through radiometric techniques as well as directly with in-situ temperature sensors.

The surface fluxes will be obtained using the covariance technique and measurements of the three-dimensional wind components and virtual temperature from fast response (10-20 Hz) sonic anemometers. The examination of the spectra and cospectra can reveal the presence of gravity waves and provide quantitative estimates of their contribution to the surface fluxes. Sonic anemometers that have proven their reliability in polar regions will be used, and calibrations and intercomparisons will be made to obtain the best quality data. Similar fast response hygrometers measure the fluctuations that are correlated with the fluid transport by the wind to derive vertical moisture fluxes. The surface radiative fluxes will be measured by four-component broadband pyrgeometers and pyranometers.

Some of the instruments will make continuous measurements during each field season of RIME, while others will make more frequent measurements during the intensive observation periods (IOPs) associated with a specific event. The soundings will be done on a 12 hourly basis, which will increase to 3 hourly during IOPs. Maintenance operations will be done as necessary but will be scheduled outside the IOPs if possible.

*Table 2. Instrumentation proposed for the RIME Supersite*

Instrument	Parameters Measured	Vertical Resolution	Temporal Resolution	Range	Notes
Soundings	profiles of T, RH; ws, wd	8 m; 50 m	12 h 3 h (IOPs)	0-15 km	
Ka-band radar	backscatter (cloud detection, $r_e$ , LWC, IWC), $V_f$ , spectral width	35 m	1 min	0.11-14 km	
S-band radar	backscatter (precip rate, cloud detection), $V_f$ , spectral width	45-105 m	30 s	0.105-8 km	
DABUL lidar	backscatter, depolarization ratio	45 m	~5 s	0.105-12 km	
50 MHz Wind Profiler	profiles of u, v, w	150 m	5 min	0.3-5 km	
449Mhz Wind Profiler	profiles of u, v, w, $C_n^2$	60-100 m	1 h	0.4-4 km	
RASS	profiles of $T_v$	60-100 m	1 h	0.4-2.5 km	
high-powered, dual-beam sodar	u, v, w, $C_T^2$	8 m	1-5 min 1 s	0-700 m	
5mm scanning radiometer	T profile	2-200 m	0.5 s	0-500 m	
sonic anemometers	$u', v', w', T_v'$ u, v, w, $T_v$	5 levels	10-20Hz	0-30 m	spectra saved, careful inter-calibration
fast hygrometers	$q'$	3 levels	20 Hz	0-30 m	spectra saved
anemometer, thermometer, hygrometer	u, v, T, q	5 levels	1 min	0-30 m	careful inter-calibration
microwave radiometer	integrated liquid water	N/A	~10 min	0-15 km	

2 broadband pyrgeometers	incoming/out going longwave radiation, $T_s$	N/A	1 min	N/A	careful calibration
2 broadband pyranometers	incoming/outgoing shortwave radiation, albedo	N/A	1 min	N/A	careful calibration
all-sky camera	cloud cover	N/A	1 min?	N/A	
particle counter	drifting/falling snow size distribution	3 levels		0 - 30 m	
barometer	surface pressure	N/A	1 min	N/A	
acoustic snow-depth gauge	snow depth/ surface height	N/A	10 min	N/A	
drift snow mass flux integrator	integrated blowing snow mass	N/A	10 min	0 - 5 m	
fine-wire thermocouples	snow T profiles	5 levels	10 min	-0.5 - +0.1 m	
thermistor string	snow T profiles	5 levels	10 min	-2.5 - -0.5 m	
Nipher snow gauge	precipitation	N/A	12-24 h	N/A	
KT-19	$T_s$	N/A	1 min	N/A	
remote sodars	u, v, w, $C_T^2$	8 m	1-5 min 1 s	0-700 m	2 sites, 25 km E-W of Supersite

### 2.3.8 Timeline for field operations

The Supersite is needed during all three field seasons for RIME (December 2006-February 2007; December 2007 - February 2008; October 2008 - February 2009). During the first field season, it is expected that the set-up of the site and the debugging of instrumentation will take 2-4 weeks. Hence, for a start date of 01 December 2006, arrival at the site should be no later than 15 November 2006. The emphasis during the first field season will be on measurements during January and February 2007, as these months have the maximum frequency of mesoscale cyclones over the Ross Ice Shelf. To minimize logistical constraints, we should aim for the early ‘resupply’ shipping in January 2006, check equipment once off ship (early February), afford 1 or more months of lead time for field preparation including gear acquisition (tents, generators, stoves), heavy Cat transport arrangement in January-February 2006, and a potential survey mission, e.g. crevasse check, on return from Pole.

In order to sample different conditions over the Ice Shelf, some instruments may be left unattended during the winters (March-October 2007; March-October 2008). These would include the basic AWS-type instrumentation, but may also include a sonic anemometer, radiation sensors, and a sodar if sufficient power can be supplied or if the site can be accessed by a traverse once or twice during the winter to provide fuel.

## 2.4 Aircraft Studies

To observe atmospheric dynamical and physical processes on both the local and regional scales as specified in the RIME detailed science plan, it is essential that multiple airborne observing platforms be employed. Only a limited set of observations of the vertical structure of the Antarctic boundary-layer and free atmosphere have been made to

date. The complex topography in the vicinity of Ross Island combined with maritime and continental air mass sources to the north and south, respectively, likely results in the formation of complex vertical boundary-layer structures. An airborne observational campaign is the only means to capture the spatial distribution of meteorological parameters throughout the local and regional study areas. Dedicated research aircraft that can sample the upper and lower troposphere have been identified as part of planning efforts for RIME. These platforms include Aerosonde UAVs, an instrumented Twin Otter and the new High-performance Instrumented Airborne Platform for Environmental Research (HIAPER). Another potentially valuable research platform is the Long-Range Aircraft for Antarctic Research (LARA) which is currently being discussed at NSF-OPP and may become available during the later stages of RIME.

#### *2.4.1 Aircraft descriptions*

##### **Aerosonde UAVs**

Aerosondes are small UAVs that have a wing-span of roughly 3 m and a payload of 3 kg. Once launched, the Aerosonde may fly a predetermined flight pattern which may be modified at any time during the flight. The airspeed of the Aerosonde is  $20\text{--}30\text{ m s}^{-1}$ . Aerosondes have been used extensively in the Arctic under a wide range of atmospheric conditions including wind speeds in excess of  $20\text{ m s}^{-1}$ , temperatures below  $-30^{\circ}\text{C}$  and in conditions of severe icing.

A range of observations can be collected using Aerosondes. Highly accurate measurements of temperature, moisture, and pressure are obtained using two Vaisala RS-90 met sensors that are calibrated before each flight. Winds are calculated to within  $0.5\text{ m s}^{-1}$  by performing a windfinding maneuver and using GPS. Newly available sensors for microphysical measurements will be used to characterize cloud and aerosol properties. An icing detector is used to warn of potential icing hazards so that evasion tactics can be employed. An array of sensors that may be used to characterize the surface will also be available including radiometric skin temperature and upwelling shortwave radiation.

##### **Twin Otters**

It is proposed that a data acquisition system be developed for use on the Twin Otter class of aircraft used by USAP to support operations out of McMurdo. Discussions have begun with Kenn Borek Air, Ltd. out of Calgary, Alberta, who operate the Twin Otters used by USAP, regarding development and installation of a data logger. It is highly desirable that the new system be tested in the field prior to the full field deployment.

To maximize the usefulness of this data system, it should be designed for use onboard any of the Twin Otter aircraft currently operated in support of the United States Antarctic Program. Requirements for such a data system include light weight, small footprint for portability, ease of mounting within the standard Twin Otter configuration, and user-friendly operation. Real-time display will permit multiple parameters with a wide range of formats to be monitored simultaneously. Atmospheric variables to be measured as part of this initial effort include temperature, pressure, wind as derived from the inertial navigation system, radar altitude, and various navigational parameters including latitude and longitude from the Global Positioning System. The data system will have the capability of supporting widely diverse user-supplied instrumentation (e.g., Nezverov

Probe for total water content, cryogenic mirror for accurate measurements of relative humidity with respect to ice at cold temperatures). The feasibility of mounting additional instrumentation from the Twin Otter platform needs to be explored. Development of such an airborne meteorological research platform is considered essential for future atmospheric studies in and around Antarctica. RIME will require the dedicated use of an instrumented USAP Twin Otter aircraft for approximately 2 months for each RIME field season.

The British Antarctic Survey (BAS) is instrumenting a Twin Otter with a suite of sensors for atmospheric studies. Instrumentation onboard the BAS Twin Otter includes the usual state parameters of wind, temperature and pressure as well as radiometric and microphysical sensors. Discussions are underway to have the BAS Twin Otter platform participate in RIME to conduct complementary research. Current planning by the BAS has their Twin Otter being deployed to McMurdo in November 2007.

### **HIAPER**

The High Performance Instrumented Airborne Platform for Environmental Research (HIAPER) is a GulfStream V (GV) business jet that has been developed under the direction of NCAR through NSF funding from the Atmospheric Sciences Program. The range (6000 nm) of HIAPER allows it to be deployed to Antarctica from remote stations in New Zealand or South America and still have several hours for on site flight patterns. This overcomes the main difficulty with operating aircraft out of McMurdo – that being the availability of an alternate runway in case of inclement weather – which prevented use of the NCAR C-130 for RIME. It has been suggested by NCAR/RAF that HIAPER may actually be able to land, refuel and change crew at McMurdo which would greatly increase the number of “on site” research hours available to the project. This possibility will be pursued further. HIAPER’s ceiling of 51000 ft is more than high enough to sample the polar vortex structure using dropsondes from well into the stratosphere to the troposphere.

A request for this facility will be made in time for its deployment during the regional scale field phase of RIME which will occur during the austral spring of 2008. By this time HIAPER should be reaching a mature stage as a research platform with an extensive complement of atmospheric instrumentation. Instrumentation planned to be available on the HIAPER by late 2008 include basic meteorological observations, gust probes, microphysics probes, dropsondes, etc.

### **Long-Range Aircraft for Antarctic Research (LARA)**

A number of research programs spanning a range of disciplines have expressed the need for a dedicated research aircraft for polar studies – particularly in the southern hemisphere. It was noted that 50 years after the IPY, a long-range airborne platform for geophysical research in Antarctica still does not exist. As a result of the NCAR C-130 being unavailable for studies based in Antarctica, a broad community of polar scientists participated in a September 2004 workshop funded by NSF to develop the scientific justification for a long-range aircraft for Antarctic geophysical research (<http://polarmet.mps.ohio-state.edu/lara/>). Because LARA would be ski-equipped, concerns regarding alternate runway status will not affect operations. This has great potential for the long-term science goals of RIME but it is not likely that such a facility



will be available prior to the 2007-2008 field season. If available, a number of RIME investigators would try to obtain its services for the study of regional scale dynamical processes, cloud microphysics and turbulence during the austral spring of 2008.

#### *2.4.2 RIME local scale process studies*

A coordinated effort between several aircraft will enable unprecedented sampling and characterization of the horizontal variability in boundary layer structure and air streams occurring within 400 km of Ross Island. The breadth of local scale processes to be studied will require two field seasons. This will also allow better coordination with the deployment of surface-based measurement systems at the Supersite which will require two seasons to become fully instrumented, but which will begin collecting valuable data during the first field season. Local scale features and processes to be studied include characterization of the nature and driving mechanisms of the RAS, quantification of the exchange of mass, momentum and heat associated with the RAS and determination of how the RAS is modulated by mesoscale cyclones. The impact that interactions between relatively warm moist air masses originating over the Ross Sea and cold/dry air masses associated with the RAS have on mesoscale cyclogenesis north of Ross Island and on local weather at McMurdo will also be studied with particular emphasis on the microphysical characteristics of low clouds and fog. Additional considerations include the influence of local-scale katabatic outflows from various glacial valleys on mesoscale cyclogenesis in this region and topographic modulation of near surface atmospheric flows.

Funds will be requested to support Aerosonde UAVs and an instrumented USAP Twin Otter to achieve the science goals related to local scale processes. The two platforms will be used in concert with the BAS Twin Otter to perform complimentary tasks during the two field deployments. As per standard Aerosonde operating procedures, four Aerosondes will be sent to McMurdo during each of the two field seasons with up to three of them being able to fly at the same time. The airborne platforms will be deployed staggered in time beginning about 4 weeks after the start date for installation of the Supersite. This will allow time for systems at the Supersite to be adequately tested prior to commencing airborne studies. The Aerosonde will be deployed about 1 week prior to requesting the Twin Otter. This will give Aerosonde operations a chance to spin up its first field deployment to Antarctica so that full scale flights could commence simultaneously with the Twin Otter flights.

The science goals to be achieved during the first two field experiments are focused on the understanding the dynamic and thermodynamic processes occurring in a region within 400 km of Ross Island. This region extends southward over the Ross Ice Shelf, westward to the Transantarctic Mountains and glacial valleys and northward to Terra Nova Bay. The processes that influence the RAS and mesoscale cyclogenesis in this region occur on a range of scales. Airborne studies will span this range of scales during the first two field seasons beginning with studies of the smaller scale processes including boundary layer evolution within the RAS, vertical cross sections of the RAS, interaction of the RAS with topographic barriers and glacial outflows. At least two aircraft (the Aerosonde and the Twin Otter) will be required to sample these scale interactions. For example, aircraft will need to be flown upstream and downstream of obstacles like Minna



Bluff and Ross Island in order to ascertain their impact on the northward flow of stable air in the RAS. An examination of changes in vertical boundary-layer structure resulting from topographic modulation can also be addressed using a combination of Aerosonde and Twin Otters flown upstream and downstream of a particular obstacle.

The vertical structure and horizontal variability of the RAS and its evolution can be studied using long duration platform such as the Aerosonde. Two Aerosondes may be flown in succession to characterize the temporal evolution of the RAS over a period of up to three days. It is hoped that an instrumented Twin Otter will also be available to sample local circulations close to terrain features in the vicinity of Ross Island or in a glacial valley where Aerosondes are unable to fly. During on-shelf flows near McMurdo strong air mass boundaries are likely to form resulting in sharp gradients in temperature and moisture and the likely occurrence of low clouds and fog. The Aerosonde's cloud and aerosol capabilities will be used to collect microphysical data in low-level clouds and fog banks while the Twin Otter will be used to sample circulation patterns associated with the onshore flow and RAS. If the BAS Twin Otter is available it could be used to collect additional cloud physics data and/or extend the region sampled during these air mass boundary events.

Studies of mesoscale cyclone processes require a sampling strategy that spans several hundred kilometers in the lowest 4 km of the atmosphere. To fully characterize the mesoscale cyclones and their interaction with the RAS and smaller scale outflows issuing from glacial valleys will require a fleet of aircraft. Studies to understand the origin of mesoscale cyclone formation and the relationship to topographic flows will be conducted. The focus will be on the region to the north of Ross Island in the western Ross Sea where mesoscale cyclone formation is most frequent. Aerosondes can be sent to the region of potential mesoscale cyclone development prior to their formation to sample the pre-environment. Once a circulation center is detected, several Aerosondes would be sent, in succession to track the system and its evolution while the USAP and BAS Twin Otters could be used to evaluate the evolving impacts on the RAS and nearby glacial outflows, particularly flow issuing from Terra Nova Bay. The BAS Twin Otter could also be designated to perform in situ cloud measurements depending on the prioritization of science objectives.

It is estimated that roughly 100 flight hours will be requested of the USAP Twin Otter and Aerosondes in the first field season and 200 flight hours in the second field season for studying local scale processes. Dedicated use of the USAP Twin Otter will be required for roughly two months during each field season while the Aerosondes will be available for 6 weeks. Current discussions with BAS indicate that their Twin Otter will be on site at McMurdo for roughly one month. It is anticipated that the BAS may contribute up to 100 flight hours as well.

#### *2.4.3 Interaction of local and regional scale processes*

Phase II goals focus on the larger-scale environment and the interaction of atmospheric processes over longer time scales. The focus will be on the *regional* studies listed in the detailed science plan. It is necessary that additional airborne facilities be considered to complete the regional-scale measurements. Of prime importance is a long-range, fully-instrumented airborne platform. Two possibilities exist that need to be

pursued. The HIAPER platform is ideal and will satisfy all measurement requirements of the regional phase of RIME. A request for this facility is still a viable option to complete Phase II of RIME as discussed in the science plan. By the austral springtime of 2008 HIAPER should be reaching a mature stage as a research platform with an extensive complement of atmospheric instrumentation. One alternative currently being investigated is operating HIAPER out of a location remote from Antarctica, such as New Zealand or South America. HIAPER has the range and speed to allow field work over the sub-polar regions and Antarctica and yet maintain a base of operations at a remote location. It is estimated that HIAPER could reach research targets to over Antarctica in as little as three hours from South America or four hours from New Zealand, leaving several hours for research before the subsequent return trip. Such a possibility will simplify the logistics that would be required for wheeled aircraft in Antarctica during the Phase II field study.

The second option is LARA, now under consideration at NSF. A recently concluded study based on the September 2004 workshop concluded there is compelling scientific justification for a long-range aircraft that can carry a comprehensive payload of desired sensors for solid earth, glaciology, atmospheric and oceanographic sciences. There is a renewed interest in developing such a platform to coincide with the upcoming 2007-2008 International Polar Year. Instrumentation of such a platform would in all probability involve support from RAF. Atmospheric instrumentation most likely would include exchangeable instrumented pods that would offer great flexibility. Since LARA would be ski-equipped, concerns regarding alternate runway status will not affect operations.

Regional topics of study include the circumpolar vortex, cyclones over the Southern Ocean and their impacts, large-scale circulations over the Ross Sea and boundary-layer flows over the Antarctic continent. The time-averaged midtropospheric circulation in the Southern Hemisphere is characterized by zonal flow around a cyclone typically centered just to the northeast of the Ross Ice Shelf. The midtropospheric cyclone center does move around causing weekly variability in the weather at Ross Island and is associated with the ENSO variability on the multiannual time scale. A field study in the Siple Coast part of West Antarctica during spring found large, persistent vertical wind shear associated with the circumpolar vortex and large spatial variations in height of the shear zone caused by the Antarctic terrain. There is little knowledge of the detailed vortex structure and the causes of its variability, primarily because of limited observations. It has long been known that cyclonic disturbances are the primary means by which the atmosphere transports heat, momentum and moisture between the poles and the middle latitudes. The Southern Ocean is known for the frequent and often intense cyclonic storms. A variety of regional-scale atmospheric processes associated with cyclone forcing and the circumpolar vortex will be examined as part of RIME. Requests to use HIAPER should be developed for submission by 01 June 2006. It is anticipated that HIAPER can reach nearly 15 km in the vertical, reaching into the lower stratosphere. Coupling of RIME objectives with issues regarding ozone depletion can be addressed. In particular, studies of vortex modulation by intense cyclones in the Southern Ocean can be conducted. Research missions will enable a detailed look at the horizontal and vertical structure of the circumpolar vortex and permit an examination as to how the troposphere and stratosphere are coupled during austral springtime, especially when the tropopause is only poorly defined and in some cases, nearly absent. Cyclonic storms over the Southern Ocean may

result in some modulation of the upper level vortex pattern and issues as to the movement and intensification of the circumpolar vortex can be examined.

Evolution of moist process associated with cyclone activity will also be emphasized in RIME Phase II. Such events also are of importance in understanding the linkage between Antarctica and middle latitude atmospheric processes. Development of large-scale cyclones in the eastern Ross Sea and attendant broad circulation features that become wrapped around Ross Island will be studied. Modulation of cold, continental air flows onto the Ross Ice Shelf to the south of Ross Island and from West Antarctica, and hence surges of the RAS will be examined. Strong air-sea interactions take place to the north of Ross Island during these episodes of cyclonic forcing, such as the opening of a large polynya at the north edge of the Ross Ice Shelf. There is evidence that such polynyas may lead to the production of bottom water, the densest component of the oceanic circulation. Processes that produce strong RAS surges that lead to polynya development need to be identified during Phase II. The distribution of cloud and precipitation associated with cyclones in the Ross Sea will be explored as well as depicting the key cloud microphysical characteristics of Antarctic and subpolar clouds. Variations in moisture and relative humidity over the Ross Ice Shelf during strong cyclone forcing will be examined and teleconnections between the Antarctica and more northerly latitudes will be examined during periods of strong cyclone forcing in the Ross Sea sector.

#### *2.4.4 Timeline for aircraft studies*

June 2005 – October 2006: Development of data acquisition system for Twin Otter platform.

November 2006: Start of RIME Phase I, USAP Twin Otter (est. 100 hours) and aerosonde flights (est. 100 hours) to map the RAS and local air flows, mesoscale cyclogenesis.

November 2007: Second field season of Phase I, detailed measurements of RAS, mesoscale cyclogenesis missions, local topographic airflow modulation studies using USAP Twin Otter (est. 200 hours), BAS Twin Otter (est. 100 hours), and aerosonde flights (est. 200 hours).

September – November 2008: Phase II of RIME, HIAPER missions (est. 150 hours) to evaluate circumpolar vortex structure and variability, sensitivity to cyclone forcing, tropospheric and stratospheric exchanges. LARA flights (est. 150 hours) to study RAS modulation by Southern Ocean cyclones, airflow studies over Ross Ice Shelf and continental interior, moist processes and cloud physics studies. Local studies of topographic flows and modulation by Southern Ocean cyclones using USAP Twin Otter platform (est. 50 hours). Aerosonde missions in support of other airborne research (est. 200 hours).

## ***2.5 Modeling Studies***

A model is the instantiation of our physical understanding at a particular instant in time. To the extent that the model agrees with reality, our understanding is complete. To the extent that there are significant differences between the results of the model and reality, this indicates that significant improvements in our understanding of either the physical phenomena and/or the physical parameters of the model must be achieved.

There is no location on Earth where the above statement is truer than Antarctica. Five years ago, a polar version of the Pennsylvania State / National Center for Atmospheric Research (NCAR) fifth generation Mesoscale Model (PMM5) was developed by The Ohio State University. This has since been incorporated into the Antarctic Mesoscale Prediction System (AMPS) operated by NCAR. AMPS is focused on McMurdo, the base of U.S. Antarctic Operations, and includes a 90-km grid covering a large portion of the Southern Hemisphere, a 30-km domain encompassing all of Antarctica, a 10-km domain covering the western Ross Sea / Ross Ice Shelf, and a 3.3-km grid (implemented in December 2001) which covers the immediate area surrounding Ross Island. The forecasts are initialized twice daily at 0000 and 1200 UTC. An archive of the AMPS forecasts exists since operations commenced in January 2001.

### ***2.5.1 Evaluation of the AMPS Archive***

The AMPS archive provides a wealth of data to be mined for understanding. First, the archive contains the twice-daily analysis fields and hence contains our best estimate of the state of the atmosphere and of the Antarctic circulation at 0000 and 1200 UTC. This information is useful for determining the spatial and temporal characteristics of the dominant synoptic and mesoscale circulation patterns in the experimental domain. Specifically, identifying ideal locations to conduct field experiments, such as the RIME Supersite, is essential for success of RIME.

The archive also contains the forecast fields and this information will be critical in making a preliminary evaluation of the skill of PMM5 in capturing terrain forced circulations such as: flow splitting around Ross Island, southerly barrier winds along the Transantarctic Mountains, katabatic flow down Byrd and Reeves Glaciers, and the northerly extent of the Ross Ice Shelf air stream. This would provide guidance as to key model weaknesses that must be targeted for development during RIME.

### ***2.5.2 Model development***

Several improvement areas have already been identified by evaluating the PMM5 results and can be targeted for development. In addition, alternative model formulations exist such as the Weather Research and Forecasting model (WRF), the Operational Multiscale Environment model with Grid Adaptivity (OMEGA), and the University of Wisconsin Regional Atmospheric Modeling System (UW-RAMS), that can be brought to bear on specific aspects. Physics processes that are known to require improvement in the model completeness and implementation include the development of the upper boundary condition, the calculation of the horizontal pressure gradient force over steep terrain (for improved simulations in the mountainous Ross Island area), the implementation of a

recently developed precipitation parameterization that accounts for clear sky precipitation and that should greatly improve precipitation predictions over the high continental interior, and the implementation of the rapid radiative transfer model for longwave radiative calculations that is merged with the existing prognostic cloud scheme, to improve temperature and moisture simulations throughout the atmospheric column.

### *2.5.3 Model intercomparison project*

A comparison of numerical weather prediction models based on a variety of synoptic situations from all seasons (identified using the AMPS archive), is necessary to identify model weaknesses based on the different parameterizations employed in each model. The comparison can identify biases that are more easily corrected, and those physical processes that are more difficult to parameterize.

### *2.5.4 Global modeling studies*

Many of the largest biases for atmospheric global climate models (AGCMs) are found in the polar regions. For example, the NCAR climate models, including the NCAR CCM3 and early versions of the NCAR CAM2 and CCSM2, show largest temperature biases over Antarctica. This is not surprising given that many AGCM parameterizations are designed for mid-latitudes and the tropics. The parameterizations for cloud radiative effects and the planetary boundary-layer are particularly affected. The displacement of the circumpolar trough several degrees to the north of the observed location by the NCAR climate models results in improper wind stress on sea ice in coupled model runs. Current model development is addressing biases in cloud radiative effects, and significant changes are anticipated for the NCAR CAM2. Resolving the very shallow Antarctic boundary-layer remains a difficult problem. The RIME observations will provide a critical resource for evaluating and adding further improvements to AGCMs. These models are a key means to demonstrate linkages to near and distant regions to the north. The AGCMs can be used to test hypotheses about the global teleconnections to the Ross Sea area. Previous modeling work has indicated that the Ross Sea area has highly significant global linkages, yet the mechanisms for these teleconnections need to be better defined. These will be detailed by the AGCM simulations.

### *2.5.5 Implementation modeling – (Numerical Weather Prediction)*

Real-time NWP support of RIME field phase activities will be necessary. Numerical models will offer forecast guidance for daily operational decisions and logistics. As has been noted in the past, global model guidance is generally insufficient for these purposes, and thus the intent is to run mesoscale models at relatively high resolution over the areas of concern. The models employed should feature polar modifications for better capturing the conditions unique to the Antarctic.

The NWP forecast products would address the needs of the program activities. This would include flight weather forecasting, personnel and equipment movements, site weather forecasting (for conditions affecting personnel and instruments), Intensive Operation Period decision making, and safety planning. Data assimilation for real-time

forecast initialization will undertake to use the available regional observations collected by the field campaign as well as other sources.

The systems developed and used must be robust. This implicates needs for reliable hardware and adequate manpower for operation. In addition, the systems would have to be in place for RIME, and thus implementation would need to be completed prior to the first RIME field phase.

Forecasts would focus on the RIME activity areas. They should be of adequate resolution and length to provide guidance for decision making.

#### *2.5.6 Resource Requirements*

Undertaking real-time mesoscale NWP demands resources in a number of areas. These include: manpower, computers, and communications. Manpower is necessary to develop, operate, maintain, and troubleshoot the system. They will also be responsible for developing and revising (per user feedback) the product suite. Computers will be necessary for running the models, and ideally would be dedicated for this purpose.

Adequate communication infrastructure will be necessary for observation, first-guess, and boundary condition acquisition.

The guidance generated must be provided to the project forecasting and operations groups. The products must be distributed reliably and on time. NWP products could be distributed as graphics via the web and as gridded fields.

### ***2.6 Satellite Remote Sensing***

RIME involves the study of atmospheric dynamics over several spatial scales. The remote sensing research component to RIME involves the interaction of mesoscale and large-scale dynamics with local thermodynamics, cloud physics, and radiative processes. Hence the observation of many meteorological phenomena and the extrapolation of many point in situ measurements to larger geographical areas are both essential to the RIME science objectives. Given the scarcity in routine meteorological measurements in Antarctica, the complete absence of such measurements over tens of degrees of latitude and longitude over the Antarctic Plateau, Ross Sea and Southern Ocean, and logistical complexities involved with specialized remote deployments of AWS units in large numbers throughout the entire region of interest, remote sensing is indispensable to RIME.

#### *2.6.1 Background*

RIME will take place during an enormous transition in Earth satellite remote sensing. The earlier "heritage" instruments, such as the five-channel Advanced Very High Resolution Radiometer (AVHRR), and passive microwave instruments on board the NOAA satellite series, having a ground instantaneous field of view (GIFOV) of tens of kilometers, will be phased out throughout this decade, in favor of sensors with orders of magnitude more spatial and spectral capability. These include the instruments aboard NASA's Earth Observing System (EOS) Terra, Aqua, and Aura platforms, related missions such as Landsat 7 and IceSAT, the phase-in of the National Polar-orbiting

Operational Environmental Satellite System (NPOESS) spacecraft, and similar remote sensing assets deployed by Europe, Japan, and India. RIME will utilize standard meteorological and oceanographic products retrieved from these sensors (e.g., by the EOS program), but will also retrieve additional geophysical variables that are both unique to the Antarctic environment and critical for this program's objectives. RIME remote sensing observations and retrievals will be used (1) in the traditional manner as information for process and case studies, and also (2) as data that can be assimilated into mesoscale and large scale modeling efforts.

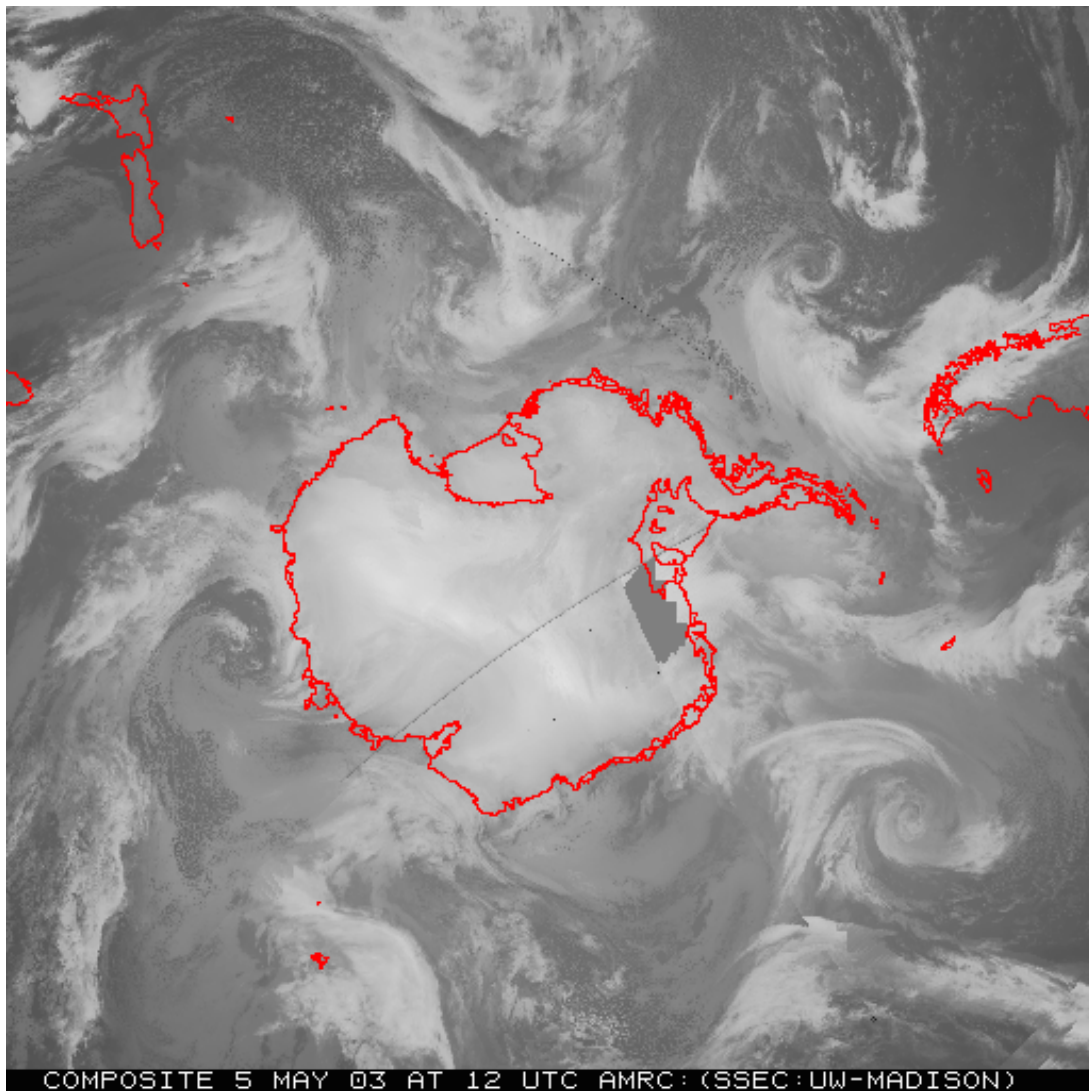
### *2.6.2 Observing global teleconnections*

One major RIME objective is to detect and quantify teleconnections between the Antarctic and lower latitudes, including the tropics. Here, satellite remote sensing has a more prominent role than in many lower latitude field experiments, due to the increased availability of data from polar orbiting spacecraft. With high inclination orbits, there are of order ten or more overpasses per day available from any given spacecraft over a given Antarctic location. This offers tremendous potential to study synoptic meteorology over vast spatial scales. For example, the Antarctic Meteorology Research Center (AMRC) at the University of Wisconsin's Space Science and Engineering Center (SSEC) has been producing composites of Antarctic NOAA and DMSP (Defense Meteorological Satellite Program) images with lower latitude imagery from geostationary spacecraft. Due to the availability of many AVHRR overpasses at high latitudes, a composite image covering nearly the entire continent, Southern Ocean, and many temperate latitudes, can be produced every three hours (See Fig. 6). The data set of AMRC composites, which presently spans more than 12 years, will be used to search for the expected teleconnections. Additional large-scale data from the EOS archive will also be brought to bear on this issue.

### *2.6.3 Satellite retrievals*

Table 3 gives a partial list of the geophysical variables that will be a part of RIME satellite remote sensing research. Many of these are available as standard EOS data products from Terra, Aqua, and Aura, but many more need to be developed and/or validated as part of RIME. For example, detection of Antarctic fog, thermodynamic phase discrimination in polar cloud, measurement of precipitation over snow/ice surfaces, identification of various stages of Antarctic ice formation at high spatial resolution, and monitoring of katabatic and barrier winds, are all polar-specific objectives that should be possible with Terra and Aqua data, but are not part of the standard EOS data product catalogue. Several polar remote sensing researchers have done some experimental work, and these efforts can be adapted and validated by RIME. In addition, many of the standard EOS products can benefit from the intensive polar validation that RIME is able to provide. Although satellite remote sensing algorithm development is not normally part of a field program, some development and validation of polar-specific retrieval techniques, and intensive validation of EOS data products over Antarctica, are essential for RIME's objectives. Table 3 is a partial list of satellite retrievals for possible investigation and utilization during RIME; additional data products may be added, as the

RIME mission planning is refined and as initial research results indicate. We also note that when a potential source is listed in Table 3, this does not necessarily mean that the variable is available as a data product that can immediately satisfy RIME's scientific objectives. The polar regions are the most challenging of all for tropospheric and surface remote sensing, and in some cases additional developmental or validation work might be warranted to satisfy RIME's requirements for satellite-retrieved parameters that we often take for granted at mid-latitudes.



*Figure 6. An Infrared Antarctic Composite satellite image made at the University of Wisconsin-Madison uses NOAA, DMSP, and a series of geostationary satellites (GOES, Meteosat, etc.) made every 3 hours since late 1992. (Courtesy of AMRC, SSEC, UW-Madison)*



*Table 3. A partial list of geophysical variables that will be potential areas of active satellite remote sensing research during RIME. Only a partial list of sources are identified.*

Variable	Potential Source or Status
Cloud amount	Terra, Aqua, NPP
Cloud top temperature	Terra, Aqua, NPP
Fog detection	Experimental
Thermodynamic phase	Terra, Aqua, NPP
Optical depth	Terra, Aqua, NPP
Liquid and ice water path	Experimental
Effective particle radius	Experimental
Cloud detection	Terra, Aqua, NPP
Near surface temperature	Experimental
Cloud drift and water vapor winds	Terra, Aqua
Vertical temperature and moisture profiles	Aqua, NPP, COSMIC
Shortwave and longwave fluxes	Aqua, NPP
Sea surface temperatures	Terra, Aqua, NPP
Katabatic wind identification and monitoring	Experimental
Ice surface temperature	Terra, Aqua, NPP
Sea ice concentration and motion	Aqua, NPP
Snow accumulation, precipitation	Aqua, NPP

#### *2.6.4 Specific RIME remote sensing projects*

As one example that illustrates how satellite remote sensing is indispensable to RIME, consider the case of studying a developing Ross Sea mesoscale cyclone in sufficient detail. Suppose we have the development of a low, driven by a katabatic flow from the Transantarctic Mountains and Ross Ice Shelf. To first identify and predict the development of this low requires regular inspection of middle infrared satellite imagery. Then, to quantify the resulting baroclinic zone over a large enough area requires satellite-based temperature sounding of the lower and mid-troposphere. This also requires that we have confidence that the sounding algorithm performs adequately over both the Ross Sea and Ross Ice Shelf (two very different surface boundary conditions, a third if we consider sea ice). The cloud layers associated with the developing then mature mesoscale cyclone would ideally be sampled by the research aircraft carrying meteorological and cloud microphysical/radiometric instruments. Dynamical conditions sampled by the research aircraft would need to be placed in a larger-scale context by satellite mapping of wind vectors (e.g., from MODIS). Also, the cloud microphysical properties of the entire system would need to be mapped using satellite data. However, algorithms to retrieve cloud properties such as thermodynamic phase, effective particle size, and liquid/ice water content, have not yet been fully tested in the polar regions, and this implies a validation effort in conjunction with the aircraft data. If successful, the satellite data could then study the entire life cycle of the mesoscale cyclone over several days,

bootstrapped by one or two research aircraft flights. In this somewhat general example, we therefore see the need for several satellite sensors, as well as investigations to ascertain confidence in the satellite algorithms for the unique Ross Sea sector environment.

To properly integrate satellite remote sensing into the overall RIME Science Plan, the following satellite research remote sensing activities are suggested below. It is suggested that these efforts need to be worked on by the whole Antarctic satellite remote sensing community.

#### *A. Development, Validation, and Retrieval of Meteorological and Oceanographic Products.*

The major focus of meteorological products is on clouds, fog, and tropospheric winds over Antarctica and the Ross Sea. This effort will include utilizing existing EOS and NPOESS products, where applicable, but validating them in the field. Where data products and algorithms do not exist in usable form, they must be developed or adapted, and validated with existing and RIME in situ data. The objective is not merely algorithm development and application to select case studies, but to produce and assimilate useful products for the entire RIME science team.

The major focus on oceanographic variables is immediately adjacent to the Ross Ice Shelf, as they respond to the meteorology observed by RIME. These include sea and ice surface temperature, sea ice concentration and motion, and identifying various stages of sea ice formation. This effort would also involve validation and refinement of atmospheric sounding algorithms, and algorithms for measuring precipitation, which are both best accomplished over the open ocean before applying them to scenes involving snow and ice surfaces.

An ancillary task is the identification of polar stratospheric clouds (PSCs) in remote sensing data. The presence of this optically thin cloud type in satellite imagery can occasionally obscure or be confused with the tropospheric cloud of interest to RIME

#### *B. Observation of Global Teleconnections.*

This effort can begin even before the major RIME field phases, and can utilize long time series available from NSIDC, AMRC, AARC, and/or EOS. See the section 2.6.2 for a more detailed example.

#### *C. Data Archival and Management.*

Resources must be allocated for "Project Office" support, including cataloguing and archiving all remote sensing retrievals in common formats, documenting quality controls on the retrievals, and providing resources for assimilating remote sensing data into the modeling efforts. The computer hardware and programming requirements for these tasks should not be underestimated. This task is to be a coordinated one between existing Antarctic archive centers (e.g. AMRC, AARC, etc.) and any defined RIME project office.

## **2.7 RIME Climate Group**

The role of Antarctica in the global climate system is an increasingly important topic considering recent climate change. The Antarctic atmospheric circulation has been linked

to the middle and low latitudes on a multitude of timescales, but is not well understood. The backdrop of the International Polar Year presents an ideal context in which to study the role of Antarctica in the global climate system. It is envisioned that RIME will provide the resources necessary for this undertaking.

### *2.7.1 Atmospheric variability*

The atmosphere varies on a wide range of space and time scales, and this variability represents the signature of climatic phenomena on Antarctica. Our knowledge of the variability characteristics of atmospheric circulation, cloud cover, precipitation, etc., is constrained by limited analysis and uncertainties in new data sources. Additional knowledge is required to fully understand and model climate variability and change.

On the interannual time scale, the largest variability is generated by the El Niño - Southern Oscillation (ENSO) phenomenon, and is concentrated in the South Pacific sector of Antarctica. The ENSO teleconnections in the South Pacific region are particularly interesting, as precursors to the ENSO warm events are often seen there. There is a strong but complex ENSO teleconnection that particularly influences the Ross Sea region. For example, the accumulation (precipitation minus evaporation) is positively correlated with the Southern Oscillation Index (SOI) from the early 1980s to 1990, and then switches to a strong negative correlation throughout the 1990s. This is primarily due to changes in the mean atmospheric circulation associated with the dominant pressure center in the circumpolar trough. The complexity of the ENSO signal, and why it can exhibit marked variability for both adjacent warm events and adjacent cold events, is a subject for further investigation.

A primary mode of variability in tropical convection is the Madden-Julian Oscillation (MJO), which occurs on intraseasonal time scales (30-60 days). A linkage between the MJO and the Antarctic may be particularly strong during August, when the teleconnection reaches deep into the Northern Hemisphere. This relationship is especially marked in the Ross Sea region. When the *interannual* teleconnection of ENSO is also considered, this suggests that a pathway of strong communication exists between the Ross Sea and the tropics on multiple time scales. The intraseasonal component of this pathway has received little attention.

The Antarctic Oscillation (AAO; also known as the Southern Annular Mode) is a see-saw in atmospheric mass, demonstrated by a strong anticorrelation in surface pressure between southern high and middle latitudes. The AAO modulates the intensity of the circumpolar vortex. In theory the AAO is concentric about the South Pole; however, observational evidence suggests that it is decidedly asymmetric with the mid-latitude signal being particularly strong to the north of the Ross Sea region. Focused areas of research are required to better understand the implications of this asymmetry, as well as the mechanisms which drive the mass exchange between high and middle latitudes.

The Antarctic Oscillation Index (AAOI) has shown a trend towards its positive polarity over the last 30 years, leading to increased westerly winds around Antarctica. This trend is most marked in the summer months, especially in the 1990s. Although some studies have linked the trend to decreases in stratospheric ozone and / or increases in atmospheric carbon dioxide, there also are tropical connections. For example, in the 1990s during the seasons of strong ENSO variability, namely, SON and DJF, the SOI and

the AAOI are significantly correlated. Both of these Southern Hemisphere oscillations create anomalous pressure changes in the South Pacific that are amplified during times of AAO / ENSO coupling. The interactions between the AAO and ENSO and their connections to the polar direct cell require further study.

### *2.7.2 Climate modeling: weaknesses in the Antarctic*

Global modeling studies are a crucial tool for evaluating the linkages between the Antarctic region and lower latitudes. However, current global climate models (GCMs) have serious deficiencies in simulating the Antarctic climate which have led to questionable results. Among these are 1) the treatment of the very stable, very shallow boundary-layer near the surface of the Antarctic ice sheet; 2) the representation of the microphysical and radiative properties of polar clouds; and 3) difficulty in properly resolving the polar tropopause. The coarse vertical resolution of GCMs often does not properly represent the fluxes of heat, momentum, and moisture within the surface boundary-layer, which may be only 5-10 m deep. Next, the improper representation of cloud fraction and cloud radiative thickness can result in large errors in the radiative fluxes. Finally, the temperature profile in the upper troposphere and lower stratosphere can have errors in excess of 10 K. This has far-reaching effects, as it impacts the circulation in the polar direct cell. RIME provides an ideal environment in which to seek solutions to these problems.

### *2.7.3 Research Plan*

Targeted modeling and observational studies can enhance our knowledge of processes which affect the Ross Sea region at climatic time scales. While some of the studies will require the enhanced database generated by Antarctic RIME field operations, others can be commenced concurrently or in advance of the field seasons. Proposed studies are outlined here.

a. Studies to better resolve the linkages between the Ross Sea region and Southern Hemisphere midlatitudes. As observations suggest that the linkage between high and middle latitudes is not necessarily symmetric, the asymmetric component of the AAO should be a part of the RIME climate analysis. The anticorrelation in surface pressure appears to be particularly high between the Ross Sea sector and the New Zealand/Australia sector. Thus, we need to better define the timescales on which this seesaw occurs. In addition, the atmospheric processes providing the linkages will need to be addressed.

b. A multiyear satellite data analysis project is a valuable tool for studying ENSO. Specifically, a study is needed employing the multiyear record and novel algorithms that will be developed as a part of RIME.

c. Data derived from ground-based and remote platforms will facilitate observational studies of atmospheric variability linkages along the West Pacific corridor, especially at intraseasonal timescales.

d. Several climate modeling studies, employing improved GCMs, will be integral for understanding the climatic linkages between the Antarctic and lower latitudes. As of now, the models have weaknesses that hinder the simulations of Antarctic climate, but those inadequacies will be addressed by the modeling group (see Section 2.5.4). Some examples are studies examining the teleconnections of ENSO, the MJO, and the AAO to the Ross Sea sector. Furthermore, the improved GCMs can be applied toward studies of the critical questions of Antarctic mass balance and the role of Antarctica in a changing climate.

#### *2.7.4 Optimizing RIME observations for climatic studies*

The field phases may not be long enough to capture multiple cycles of intraseasonal variability. Therefore, maintenance of the some components of the Supersite and other observational platforms between field seasons is particularly important, for example, for studying the linkages between the MJO and the Ross Sea region. In addition, there is a good possibility that an extreme in the ENSO cycle will occur between these periods, which may allow a limited case study.

The new AWS sites, which will be installed for RIME field phases, will eventually provide a continuous climatological data source which will last for years beyond RIME. This will be useful in examining atmospheric variability across the Ross Ice Shelf at multiple timescales ranging from intraseasonal to interannual.

### **3. ORGANIZATIONAL CONSIDERATIONS**

Discussions were held at the recent RIME Implementation Plan Workshop to implement a steering committee and project office to enhance communication and coordinate efforts among scientists participating in RIME.

#### *3.1 RIME Science Steering Committee Organization*

The scientific and coordination oversight for RIME will be vested in a Science Steering Committee (SSC). SSC membership will be made of RIME Project Investigators. The initial membership of the SSC is as follows (\*-co-chair):

David Bromwich*	Byrd Polar Research Center, Ohio State U.
John Cassano	CIRES, U. of Colorado
Bill Kuo/Jordan Powers	NCAR-MMM
Bill Neff/Ola Persson	NOAA-ETL
Tom Parish*	U. of Wyoming
James Moore	UCAR-JOSS
James Pinto/Von Walden	NCAR-ATD/U. of Idaho
Tom Lachlan-Cope	British Antarctic Survey
Mat Lazarra/Dan Lubin	U. of Wisconsin/Scripps Inst. Of Oceanography
Art Cayette	SPAWAR

The SSC will follow terms of reference outlined in the RIME Detailed Science Plan. Plans call for membership on a rotating basis with two-year terms.

### ***3.2 RIME Science Management Office (R-SMO)***

The SSC has recommended the formation of a RIME Science Management Office (R-SMO) to provide scientific, technical, logistical and administrative support. The UCAR Joint Office for Science Support (JOSS) will be requested to house the R-SMO and provide services to assist with planning, organizing and implementing the field campaign. Specific duties of the R-SMO will include:

- Support to the SSC and any other committees formed to carry out project objectives
- Support to project meetings
- Coordinate communication among the participants includes the updating and maintenance of the RIME Project Website
- Coordinate with NSF and the Antarctic support contractor to meet project needs
- Develop and implement a project data management strategy
- Arrange for project communications and power needs during the field campaigns
- Support the preparation and distribution of project publications including Operations and Data Management Plan

The RIME Project has proposed 3 seasonal field campaigns during the next 5 years. They are: December 2006 - January 2007, November 2007 - February 2008, and September 2008 - February 2009. These intensive field campaigns will be used by participants to make the several scales of measurements required to answer the key RIME science questions. Each of these periods will include intense high resolution observations from special surface and airborne platforms. The special observing platforms will include several different aircraft from international facilities, a surface Supersite on the Ross Ice Shelf with a variety of meteorological, radiation and chemistry sensors from different groups, special upper air soundings and automated weather stations deployed in the region of interest. Each of these facilities would be used during portions of the three field seasons, depending on measurements required to answer key questions. In addition, some instruments at the Supersite will be left unattended in the interim periods of March – October 2007 and Mar – August 2008. Supporting high resolution operational data collection from surface and satellite platforms will be required.

The R-SMO will work with the participants to determine priorities and to assure that operational strategies are implemented to achieve project science objectives. A RIME Operations Plan will be prepared and distributed prior to each field season that reflects the details of field coordination, surface data collection strategies and aircraft flight plans. The R-SMO will work closely with the USAP support and logistics contractor to make arrangements for critical items such as:

- RIME Operations Center at McMurdo to be used during the 3 intensive field campaigns including LAN networking, access to the Internet, etc.
- Communications network to support successful and safe accomplishment of RIME science objectives including radios and satellite systems as necessary to exchange voice, text and data messages
- Weather forecast and air traffic control support

The project proposes to have staff on site in the operations center during the deployment of any special facilities (e.g. aircraft, Ross Ice Shelf sounding sites, Supersite) during the 3 intensive campaign periods noted above.

### ***3.3 Logistics***

Researchers seeking a National Science Foundation (NSF) grant for work in Antarctica may be requested to complete an Operational Requirements Worksheet (ORW) in addition to their proposal as part of the review process. Funded projects are also required to complete a Support Information Package (SIP) for each year of deployment to detail all logistical and support needs, and to better plan appropriate mission resources.

Participant **On-Line Antarctic Resource Information Coordination Environment (POLAR ICE)** is a web based tool for funded investigators to specify support needs while deployed in Antarctica. The R-SMO will work with the science team to complete all required documentation and coordinate with the NSF and Raytheon Polar Services Company, the current U.S. Antarctic Program support and logistics contractor. A deployment timeline will be organized and updated on the R-SMO website and will include shipping and travel details, safety training and field deployment schedules.

### ***3.4 Data Management Considerations***

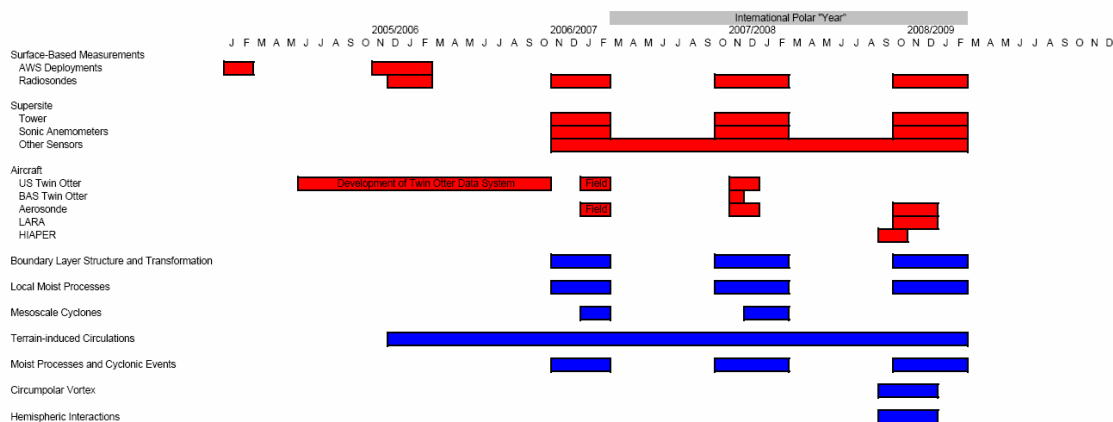
The size, complexity and duration of RIME suggest that a comprehensive data management strategy will be crucial to the success of the project. The project will need an integrated data archive that has easy and timely access by a large community of investigators. The R-SMO will be responsible for developing and implementing an integrated data management strategy and providing coordination among investigators, data users and data archive centers. Some particular data management challenges in RIME include;

- the availability of data (e.g. Supersite, satellite, AWS, aircraft, soundings) in the field campaigns to aid real-time decision making (e.g. aircraft coordination, mission selection) and meet safety requirements (e.g. personnel at the Supersite and sounding sites)
- the catalog and archival of a variety of satellite data and products (e.g. conversion to common formats, output datasets for model work)

The UCAR Joint Office for Science Support (JOSS) would be asked to develop and implement the RIME data management strategy in close coordination with the R-SMO

and SSC. Initial steps in this process will be to determine data requirements using a data management questionnaire distributed to all participants, followed by the preparation of a data management plan with the implementation procedures and protocols developed for RIME. This will include data documentation and format guidelines to maximize data exchange and increase data analysis and synthesis activities. It is likely that RIME will adopt a decentralized archive where data may reside at one or more archive centers or institutions (e.g. U. of Wisconsin, NOAA/ETL, Byrd Polar Research Center, NASA/DAAC) linked together via a RIME data management page accessible at the RIME Project website. The R-SMO and JOSS will assure adherence to the NSF/OPP Data Policy and data documentation requirements from the U.S. Antarctic Data Coordination Center (USADCC).

### 3.5 Project Timeline



### 3.6 Budget

A very rough estimate of the resources RIME will require is given in Table 4. These numbers are subject to revision based on the projects funded by NSF through the normal peer-review process. Note that the 2004/05 budget entries are currently funded.

*Table 4. RIME budget estimates by observation type/discipline. Estimates are in millions of dollars and assume the following: 1) the Supersite continuously operates from 2007-09, 2) the U.S. Twin Otter is “provided” by USAP, 3) the LARA estimate is for deployment cost only, 4) the HIAPER aircraft funds are funneled through the NSF deployment pool, 5) the 2010-12 resources are for analysis activities.*

Year	04/05	05/06	06/07	07/08	08/09	June 09 – June 12
Regional Surface-Based Array	.2	.5	.8	.8	.8	.5/yr
RIME Supersite	--	.8	2.0	1.0	1.0	.5/yr
Aircraft Studies	--	.1	.5	1.0	2.0	.5/yr
Modeling	.3	.5	.5	.5	.5	.5/yr



Satellite Remote Sensing	--	.5	.5	.5	.5	.5/yr
Climate Studies	--	.5	.5	.5	.5	.5/yr
Support (e.g., R-SMO mtgs, data mgmt)	--	.2	.3	.3	.4	.2/yr
Total		.5	3.1	5.1	4.6	5.7
						3.2/yr

### ***3.7 Education and Outreach***

Antarctic RIME will foster numerous outreach activities:

- Graduate students educated under RIME grants.
- Educational websites with results coordinated through R-SMO.
- All RIME data sets will be made available for community use through R-SMO.
- Targeted publications (i.e., special journal issues) will synthesize RIME research.
- RIME science meetings will bring together scientists and students working on RIME projects. In addition, it is anticipated RIME special sessions will be organized at national and international meetings such as the fall AGU meeting in San Francisco, the AMS Polar Meteorology and Oceanography Meeting, IUGG/IAMAS symposia, and the SCAR annual science meeting.
- International collaborations will foster the exchange of ideas, information, and personnel.
- The SSC will coordinate K-12 outreach at the local level.

### ***3.8 Links to Related Programs and Activities***

It is envisioned that Antarctic RIME scientists will interact with the following groups:

- THORPEX (<http://www.wmo.int/thorpex>) – Conduct joint research on topics of mutual interest, especially meridional atmospheric interactions.
- ANTCI (Antarctic Tropospheric Chemistry Investigation; [http://acd.ucar.edu/~mauldin/ANTCI\\_Web/ANTCI\\_Home.htm](http://acd.ucar.edu/~mauldin/ANTCI_Web/ANTCI_Home.htm)) – Coordinate flight and field activities.
- CLIVAR (International Research Programme on Climate Variability and Predictability; <http://www.clivar.org/>) – Integrate an Antarctic perspective into CLIVAR studies.
- ITASE (International Transantarctic Science Expedition; <http://www.ume.maine.edu/itase/>) – Coordinate field activities, exchange ice core and model results.
- IPY (International Polar Year; <http://www.ipy.org/>) – Coordinate field activities to coincide with this historic event and take advantage of the interdisciplinary activities that are planned.
- SCAR (Scientific Committee on Antarctic Research; <http://www.scar.org/>) – Integrate research into the broader goals of SCAR.

- WAIS (West Antarctic Ice Sheet Initiative; <http://igloo.gsfc.nasa.gov/wais/>) – Draw on WAIS results and extend them to the Ross Sea region.
- BAS (British Antarctic Survey; <http://www.antarctica.ac.uk/>) – Collaborative exchanges with BAS are planned. For example, the BAS Twin Otter has been scheduled for participation in RIME during November 2007.
- PNRA (Italian National Research Program in Antarctica; <http://www.pnra.it/>) – Observational collaborations are planned. For example, PNRA has expressed interest in participating in intensive radiosonde launching campaigns during the RIME field phases.